



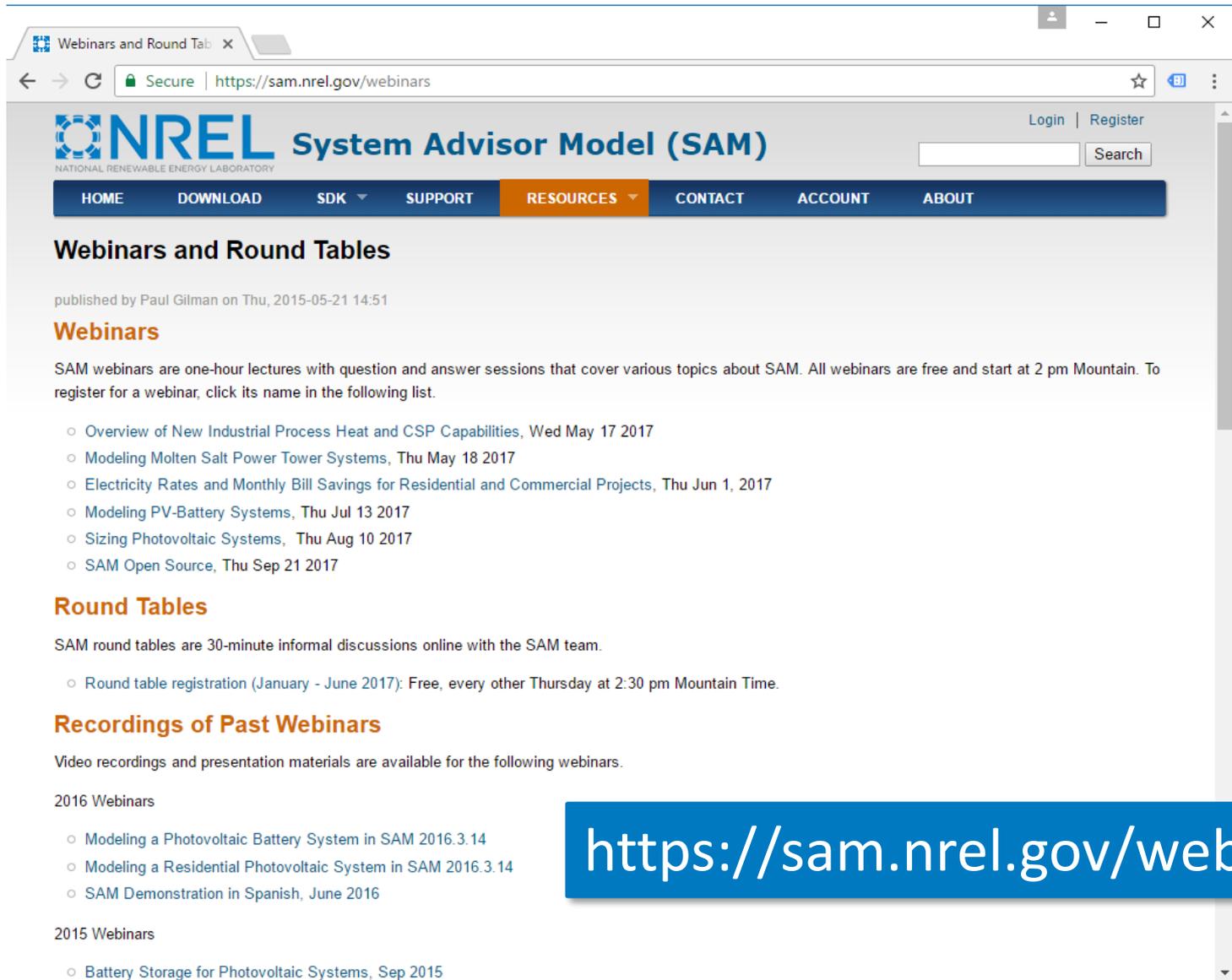
## **SAM Webinars 2017: Modeling Molten Salt Power Tower Systems in SAM 2017.1.17**

Mike Wagner

May 18, 2017

- Overview of New Industrial Process Heat and CSP Capabilities, May 17
- **Modeling Molten Salt Power Tower Systems, May 18**
- Electricity Rates and Monthly Bill Savings for Residential and Commercial Projects, June 1
- Modeling PV-Battery Systems, July 13
- Sizing Photovoltaic Systems, August 10
- SAM Open Source, September 21

# Registration Links and Webinar Recordings



The screenshot shows a web browser window with the URL <https://sam.nrel.gov/webinars>. The page header includes the NREL logo and the text "System Advisor Model (SAM)". A navigation menu contains links for HOME, DOWNLOAD, SDK, SUPPORT, RESOURCES, CONTACT, ACCOUNT, and ABOUT. The main content area is titled "Webinars and Round Tables" and includes a publication date: "published by Paul Gilman on Thu, 2015-05-21 14:51".

## Webinars

SAM webinars are one-hour lectures with question and answer sessions that cover various topics about SAM. All webinars are free and start at 2 pm Mountain. To register for a webinar, click its name in the following list.

- Overview of New Industrial Process Heat and CSP Capabilities, Wed May 17 2017
- Modeling Molten Salt Power Tower Systems, Thu May 18 2017
- Electricity Rates and Monthly Bill Savings for Residential and Commercial Projects, Thu Jun 1, 2017
- Modeling PV-Battery Systems, Thu Jul 13 2017
- Sizing Photovoltaic Systems, Thu Aug 10 2017
- SAM Open Source, Thu Sep 21 2017

## Round Tables

SAM round tables are 30-minute informal discussions online with the SAM team.

- Round table registration (January - June 2017): Free, every other Thursday at 2:30 pm Mountain Time.

## Recordings of Past Webinars

Video recordings and presentation materials are available for the following webinars.

### 2016 Webinars

- Modeling a Photovoltaic Battery System in SAM 2016.3.14
- Modeling a Residential Photovoltaic System in SAM 2016.3.14
- SAM Demonstration in Spanish, June 2016

### 2015 Webinars

- Battery Storage for Photovoltaic Systems, Sep 2015

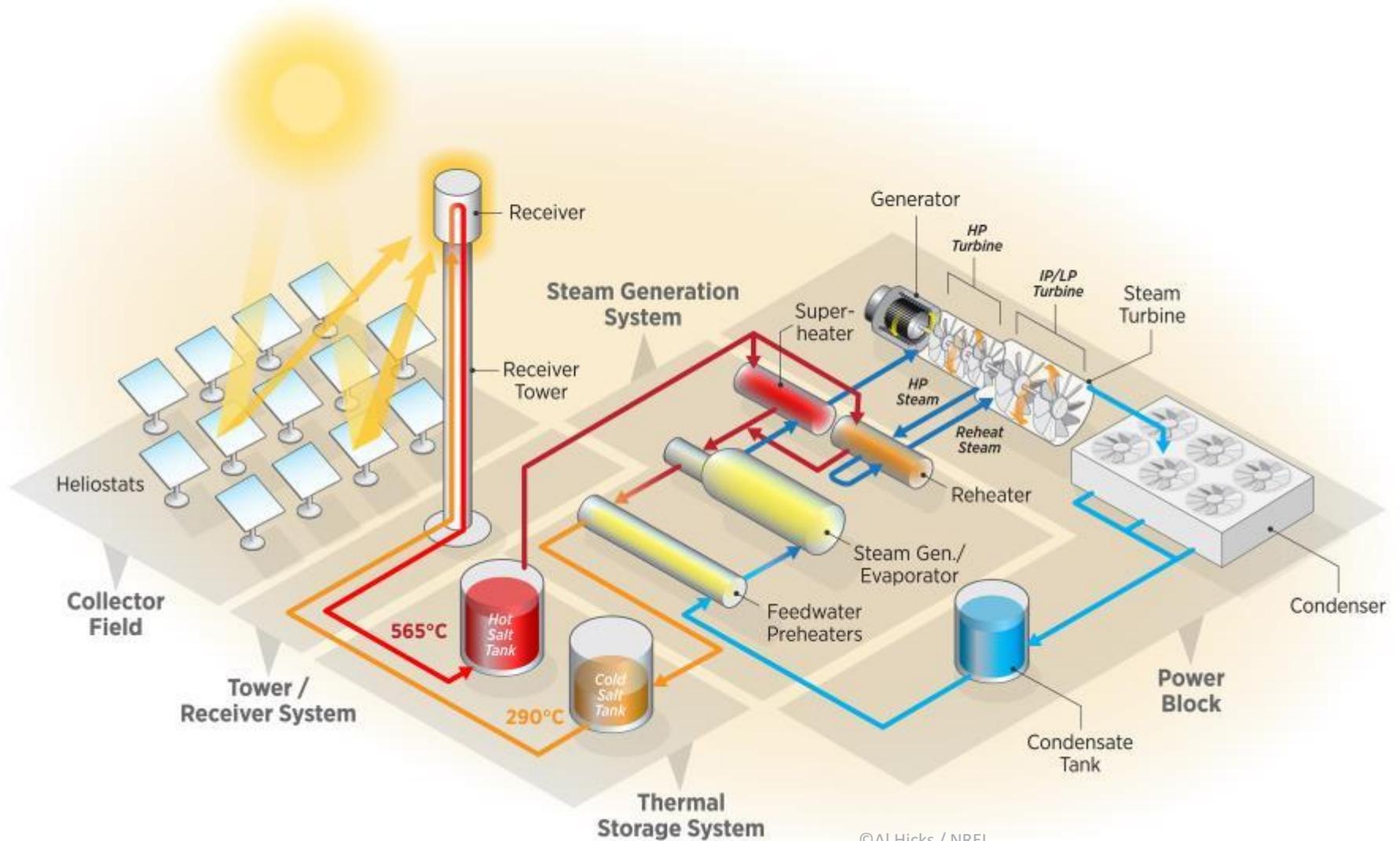
<https://sam.nrel.gov/webinars>

# Outline

- Model updates and improvements
- Demo
  - Design point DNI
  - Optimizing solar field geometry
  - Dispatch optimization
- Question & Answer (20 minutes)

# Model updates and improvements

# System description



# How SAM models MSPT systems

1. Design stage
  - Optimization
  - Final layout
2. Optical characterization
3. Performance simulation
  - Plant operations schemes: heuristic dispatch or optimized dispatch

# Updates and improvements

- User-defined power cycle
- Dispatch optimization
- Hourly time-of-dispatch factors
- Improved solar field performance availability specification
- User specification of attenuation loss coefficients

# User-defined power cycle

- Allows specification of detailed performance of a custom cycle
- Performance depends on:
  - HTF mass flow
  - HTF temperature
  - Ambient temperature
- Interactions between variables can be modeled

**Select option from dropdown**

**System Design Parameters**

Power cycle gross output	115	MWe
Estimated gross to net conversion factor	0.9	
Estimated net output (nameplate)	103.5	MWe

**General Design Parameters**

Pumping power for HTF through power block	0.55	kW/kg/s
Fraction of thermal power needed for standby	0.2	
Power block startup time	0.5	hours
Fraction of thermal power needed for startup	0.5	
Minimum turbine operation	0.2	
Maximum turbine over design operation	1.05	

**User Defined Power Cycle** ▾

**User Defined Power Cycle Design Parameters**

Ambient temperature	43	°C	Gross power co
Cooling system water usage	0	kg/s	Gross power co
HTF mass flow rate	652.4	kg/s	

**Performance as Function of HTF Temperature**

Low, design, and high mass flow rates (m) for parameter interactions with HTF temperature:

Low normalized HTF m	0.3
Design normalized HTF m	1.0
High normalized HTF m	1.2

Import... Export...

HTF temperature °C (at HTF m ⇒)	W cycle low	W cycle design	W cycle high	Heat in low	Heat in design	Heat in high	W cool low
500	0.143233	0.685149	0.768941	0.221831	0.739437	0.887324	1
504.211	0.146807	0.702248	0.788132	0.226279	0.754262	0.905115	1
508.421	0.150404	0.719451	0.807439	0.230726	0.769088	0.922906	1

# Dispatch optimization

- By default, SAM generates power whenever energy is available in the storage system
- Dispatch optimization calculates the best times to generate, and determines an optimal operating profile (more on this later!)

**Enable with checkbox**

**Plant Energy Consumption**

Fraction of rated gross power consumed all times: 0.0055 MWe/MWcap

	Factor	Coeff 0	Coeff 1	Coeff 2	
Balance of plant parasitic	1	0	0.483	0	BOP: 0 MWe
Aux heater boiler parasitic	1	0.483	0.571	0	Aux: 2.78783 MWe

**Availability and Curtailment**

Constant loss: 4.0 %  
Hourly losses: None  
Custom periods: None

**Dispatch Optimization**

Enable dispatch optimization

Time horizon for dispatch optimization	48 hour	Objective function time weighting exponent	0.99
Frequency for dispatch reoptimization	24 hour	Maximum branch and bound iterations	35000
Cycle startup cost penalty	10000 \$/start	Solution optimality gap tolerance	0.001
Receiver startup cost penalty	950 \$/start	Optimization solver timeout limit	5 sec
Power generation ramping penalty	0.1 \$/ΔkWe	Max. net power to the grid	1e+038 MWe
		Max. net power to the grid (incl. availability)	9.6e+037 MWe

# Hourly time-of-dispatch factors

Enable with dropdown

PPA multipliers entered at the weather file time step.

Hourly (subhourly) PPA multipliers

Click to edit time series data

Enter factors in the table – one for each time step

	Value
1	0.7
2	0.7
3	0.7
4	0.7
5	0.7
6	0.7
7	0.8
8	0.8
9	1.1
10	1.1
11	1.1
12	1.1
13	1.1
14	1.1
15	1.1
16	1.1
17	1.1

# Improved solar field performance availability specification

**Edit Losses**

Constant loss (%)

Enable hourly losses (%)

Enable hourly losses with custom periods

**Edit Data**

Hourly Values (8760)

	Value
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0

**Heliostat field availability**

Constant loss: 0.0 %  
Hourly losses: None  
Custom periods: None

Curtailed and availability losses reduce the solar field output to represent component outages, soiling, or other events.

Mirror reflectance and soiling

Heliostat availability

**Simulation Controls**

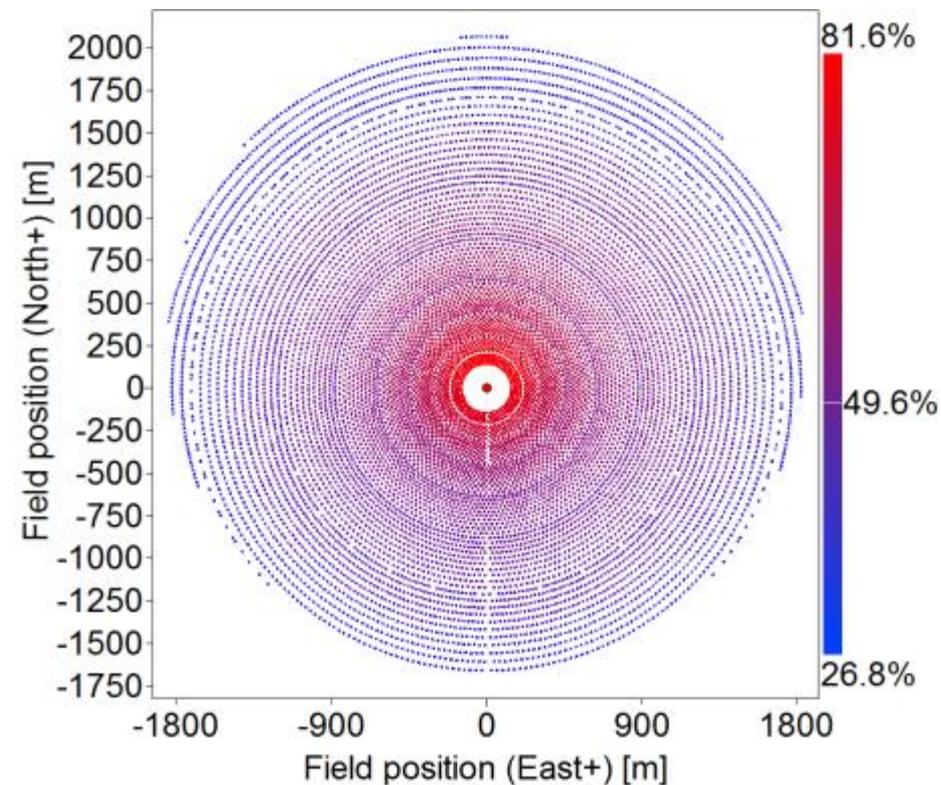
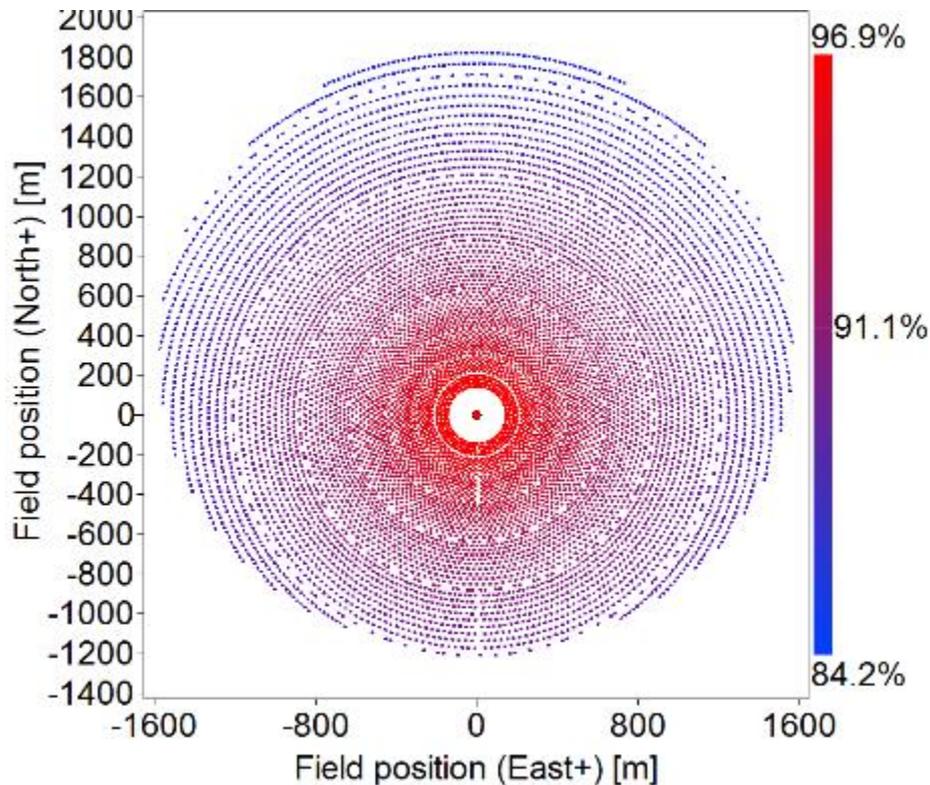
# User specification of attenuation loss coefficients

- Atmospheric attenuation models the loss due to atmospheric scattering between each heliostat and the receiver
- This varies as a function of aerosol optical depth (AOD)
- AOD is highly location-dependent and varies throughout the day and year
- SAM's defaults are for 25 km visibility in the US southwest and are likely not appropriate for MENA sites
- Polynomial is evaluated for each heliostat position to determine overall performance

Atmospheric Attenuation	
Polynomial coefficient 0	0.006789
Polynomial coefficient 1	0.1046 1/km
Polynomial coefficient 2	-0.017 1/km <sup>2</sup>
Polynomial coefficient 3	0.002845 1/km <sup>3</sup>
Average attenuation loss	9.0 %

# Attenuation loss example

Coefficient	Clear (25km)	Hazy (5km)
0	0.006789	0.01293
1	0.1046	0.2748
2	-0.017	-0.03394
3	0.002845	0
<b>Avg.</b>	<b>9%</b>	<b>26%</b>



# Design-point DNI selection

# Design-point DNI selection

- Definition: *The direct normal irradiance (DNI) available at the design point*
- Increasing this value indicates that fewer heliostats are needed to achieve the reference condition power
- Should represent the DNI at which your plant should achieve the specified thermal rating
- SAM uses the sun position at noon on the summer solstice (June 21 north of the equator, and December 21 south of the equator)

# Selecting a design-point DNI value – default case

The screenshot shows the SAM 2017.1.17 software interface. The left sidebar contains a navigation menu with the following items: Tower (salt), Single owner; Location and Resource; System Design; Heliostat Field; Tower and Receiver; Power Cycle; Thermal Storage; System Control; System Costs; Lifetime; Financial Parameters; Time of Delivery Factors; Incentives; and Depreciation. At the bottom of the sidebar, there is a 'Simulate' button and a 'Parametrics' / 'Stochastic' / 'P50 / P90' / 'Macros' section.

The main window is titled 'untitled' and has a menu bar with 'File', '+ Add', and 'Help'. The main content area is divided into several sections:

- Download a weather file from the NREL NSRDB:** This section includes a 'Download...' button and a text box explaining that users can click 'Download' and type a street address or latitude and longitude to download a weather file from the NREL NSRDB. A note in red text states: "SAM's CSP models use a different time convention for weather data than the NREL NSRDB. See Help for details." Below this is a link to 'NSRDB Map'.
- Choose a weather file from the solar resource library:** This section includes a search box and a dropdown menu. Below is a table of weather files from the library:

Name	Station ID	Latitude	Longitude	Elevation
USA CA Crescent City Faa Ai (TMY3)	725946			
USA CA Daggett (TMY2)	23161			
USA CA Daggett Barstow-daggett Ap (TMY3)	723815	34.85	-116.8	588
USA CA Edwards Afb (TMY3)	723810	34.9	-117.867	706
USA CA Fresno (TMY2)	93193	36.7667	-119.717	100
USA CA Fresno Yosemite Intl Ap (TMY3)	723800	36.783	-119.717	102

An orange callout box with the text "View data for Daggett, CA location" has an arrow pointing to the 'View data...' button in the 'Tools' section on the right.

Below the table, the 'City' is set to 'Daggett', 'State' to 'CA', 'Country' to 'USA', 'Time zone' to 'GMT -8', 'Latitude' to '34.8667 °N', 'Elevation' to '588 m', 'Longitude' to '-116.783 °E', 'Data Source' to 'TMY2', and 'Station ID' to '23161'. The 'Data file' path is 'C:\SAM\2017.1.17\solar\_resource\USA CA Daggett (TMY2).csv'.

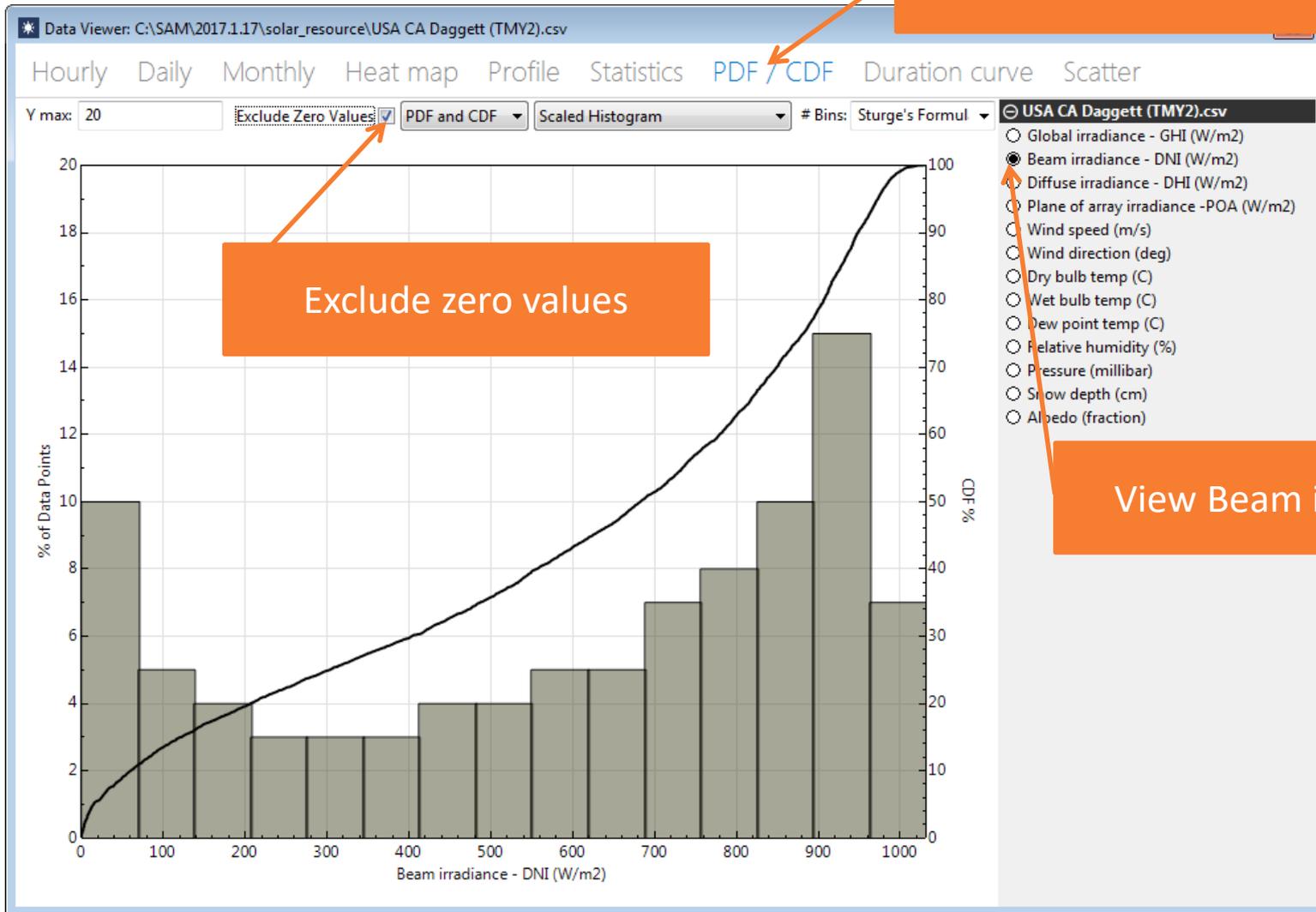
**-Annual Weather Data Summary**

Global horizontal	5.86 kWh/m <sup>2</sup> /day	Average temperature	19.8 °C
Direct normal (beam)	7.65 kWh/m <sup>2</sup> /day	Average wind speed	4.9 m/s
Diffuse horizontal	1.34 kWh/m <sup>2</sup> /day		

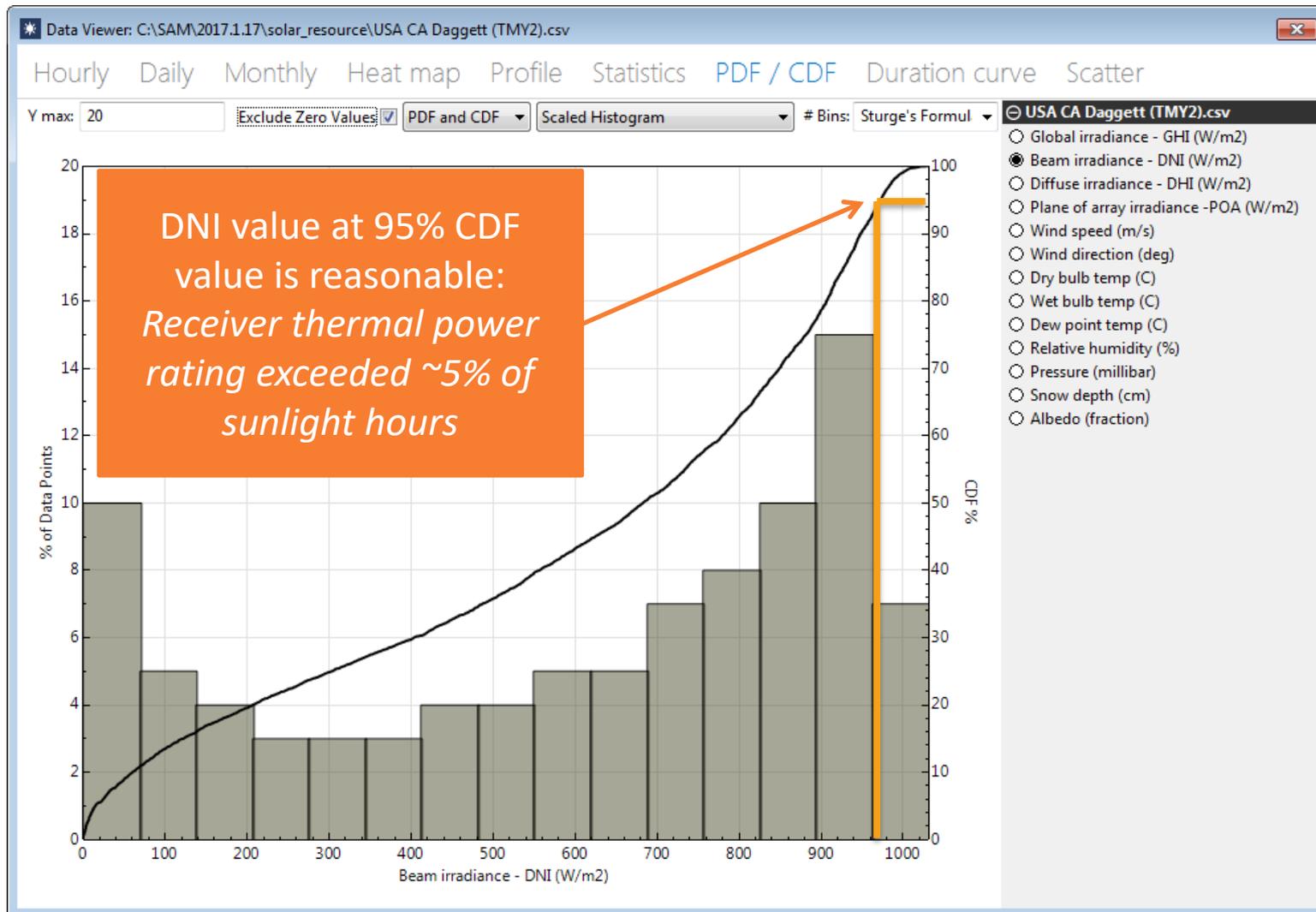
A link to 'Visit SAM weather data website' is provided.

- Use a specific weather file on disk:** This section includes a 'Browse...' button and a text box explaining that users can check the box and click 'Browse' to choose a weather file stored on their computer without adding it to the solar resource library. Supported solar weather file formats are SAM CSV, TMY2, TMY3, and EPW.

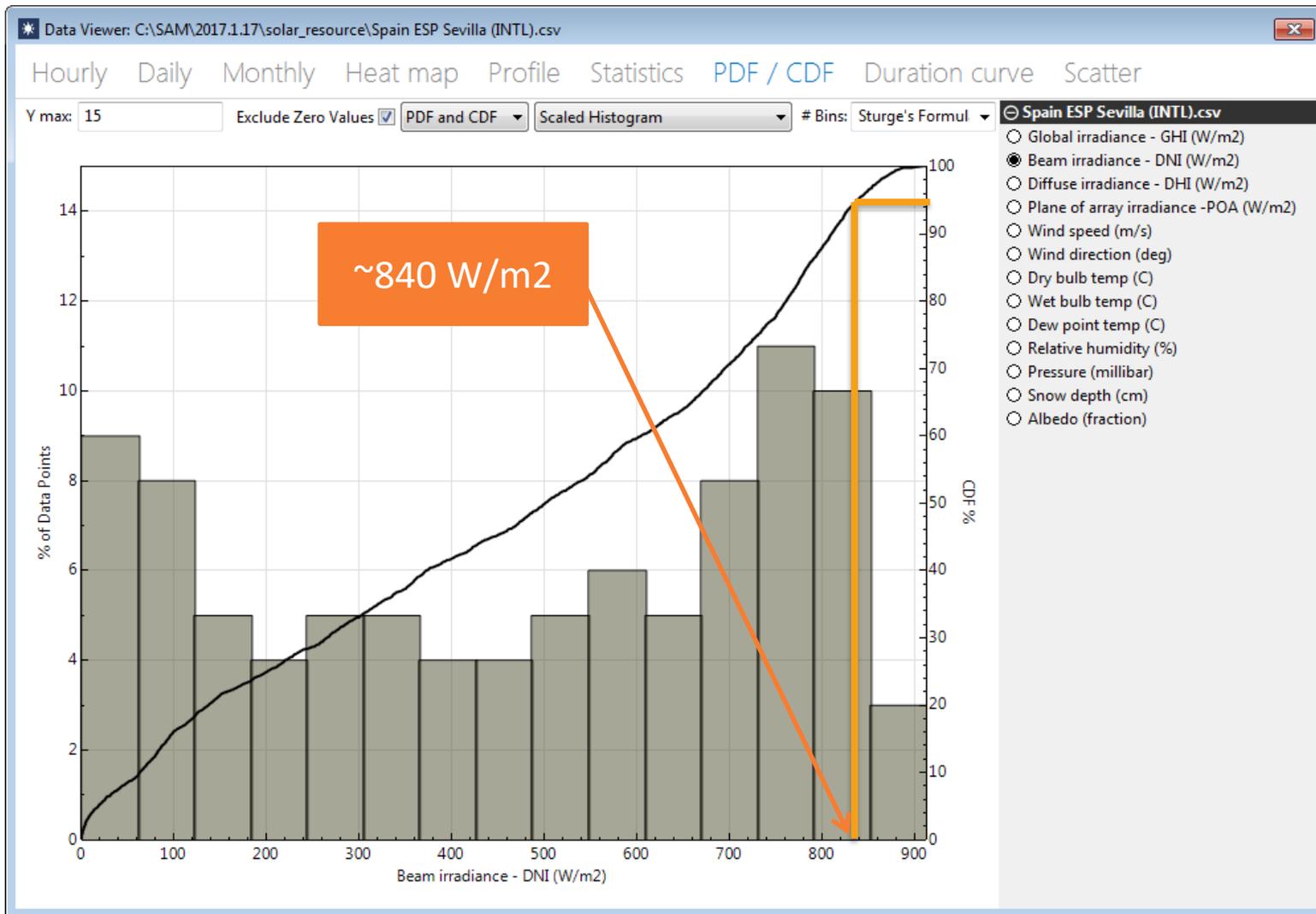
# Selecting a design-point DNI value – default case



# Selecting a design-point DNI value – default case

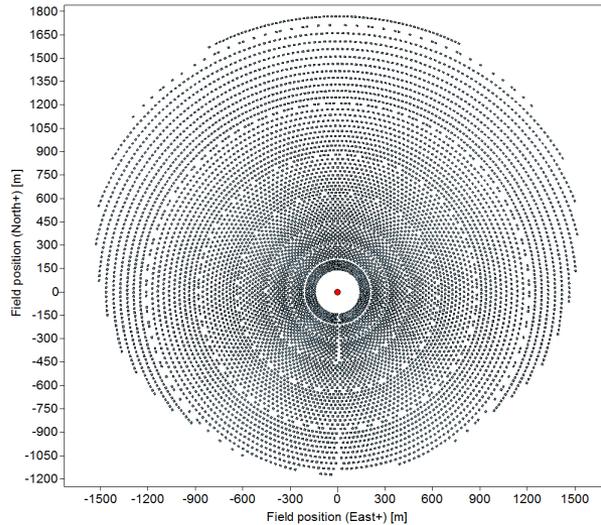


# Example for different climate – Sevilla, Spain

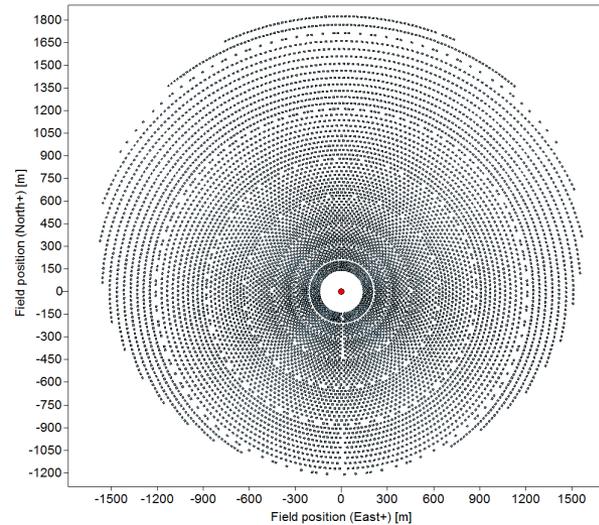


# Layout implications

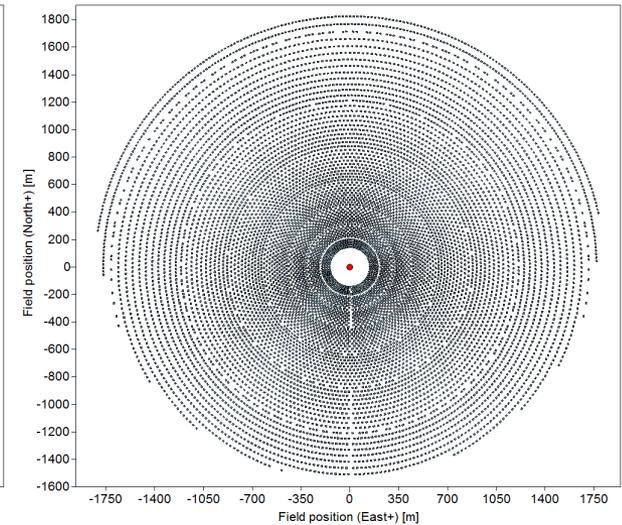
980 W/m<sup>2</sup>  
8,324



950 W/m<sup>2</sup>  
8,661



840 W/m<sup>2</sup>  
10,163



- Heliostat count does not scale linearly!

# Selecting a design-point DNI value – default case

## Potential pitfalls:

- DNI design point and solar multiple control separate design aspects
  - Solar multiple describes the relative thermal size of the *receiver* and *power cycle*
  - DNI design point controls the relative thermal size of the *heliostat field* and the *receiver*
- Several inputs should be aligned with the selected design point
  - Design and operation limits on the Tower and Receiver page
  - Maximum receiver flux – if design DNI is below maximum observed

### Design and Operation

Minimum receiver turndown fraction	0.25
Maximum receiver operation fraction	1.2
Receiver startup delay time	0.2 hr
Receiver startup delay energy fraction	0.25
Receiver HTF pump efficiency	0.850
Maximum flow rate to receiver	1878.77 kg/s

### Receiver Flux Modeling Parameters

Maximum receiver flux	1000 kWt/m <sup>2</sup>
Estimated receiver heat loss	30.0 kWt/m <sup>2</sup>
Receiver flux map resolution	20
Number of days in flux map lookup	8
Hourly frequency in flux map lookup	2 hours

# Optimizing solar field geometry

# Motivation

- MSPT design process is not as straightforward as other technologies
- Changes in sizing, site, or components requires new solar field design
- Many variables *could* be optimized
- SAM optimizes tower height, receiver height, receiver diameter, and heliostat positions
- SAM provides a tool to automate this process
  - Generate heliostat layout (for current receiver and tower geometry)
  - Optimize solar field geometry

# Case study

- Consider a “peaking” plant that generates during limited high-value time periods

Parameter	Units	Value
Design turbine gross output	MWe	115
Solar multiple	-	1.3
Peak hours	-	7-9; 17-21
Peak multiplier	-	3
Hours of TES	Hours	8

# System design settings

SAM 2017.1.17: C:\Users\mwagner\Documents\NREL\SAM\SAM Presentations\Webinar\_Towers\_2017-5-18\do-case.sam

File Add untitled (1) Help

Tower (salt), Single owner

Location and Resource

System Design

Heliostat Field

Tower and Receiver

Power Cycle

Thermal Storage

System Control

System Costs

Lifetime

Financial Parameters

Time of Delivery Factors

Incentives

Depreciation

Simulate > Parametrics Stochastic P50 / P90 Macros

**Design Point Parameters**  
The design point parameters determine the nominal ratings of each part of the power tower system. After specifying the design point parameters here, you can specify details of each component of the system on the Heliostat Field, Tower and Receiver, Thermal Storage, and Power Cycle input pages.

**-Heliostat Field-**

Design point DNI	950 W/m <sup>2</sup>
Solar multiple	1.3
Receiver thermal power	363 MWt
Heliostat field multiple	1

**-Tower and Receiver-**

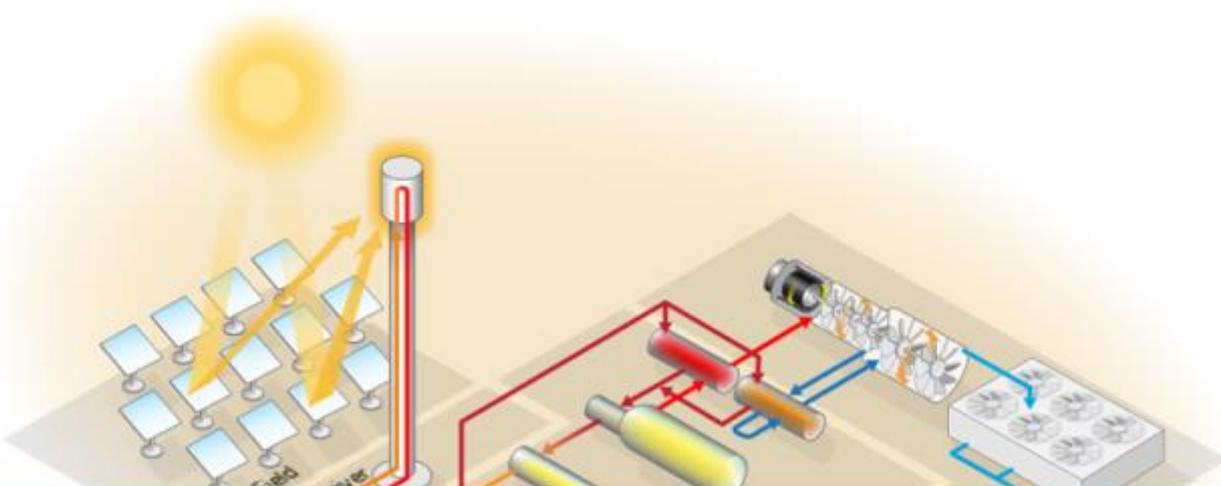
HTF hot temperature	574 °C
HTF cold temperature	290 °C

**-Thermal Storage-**

Full load hours of storage	8 hours
Solar field hours of storage	6.15385 hours

**-Power Cycle-**

Design turbine gross output	115 MWe
Estimated gross to net conversion factor	0.9
Estimated net output at design (nameplate)	104 MWe
Cycle thermal efficiency	0.412
Cycle thermal power	279 MWt



# TOD settings

SAM 2017.1.17

File Add untitled Help

Tower (salt), Single owner

Location and Resource

System Design

Heliostat Field

Tower and Receiver

Power Cycle

Thermal Storage

System Control

System Costs

Lifetime

Financial Parameters

Time of Delivery Factors

Incentives

Depreciation

Simulate >

Parametrics Stochastic

P50 / P90 Macros

### TOD Schedules and Factors

Use library values

PPA price multiplier

Period 1: 1

Period 2: 3

Period 3: 1

Period 4: 1

Period 5: 1

Period 6: 1

Period 7: 1

Period 8: 1

Period 9: 1

PPA price multipliers, or TOD factors, apply to the PPA price according to the weekday and weekend schedules.

TOD factor data in SAM's library may not be applicable to your project. Be sure that your assumptions are consistent with the requirements described in the appropriate solicitation documents.

#### Weekday Schedule

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Feb	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Mar	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Apr	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
May	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Jun	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Jul	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Aug	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Sep	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Oct	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Nov	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Dec	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1

#### Weekend Schedule

	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Jan	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Feb	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Mar	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Apr	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
May	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Jun	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Jul	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Aug	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Sep	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Oct	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Nov	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1
Dec	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	2	2	2	2	2	1	1

Save / Load Data

Save data to file... Load data from file...

# Choosing optimization settings

- Initial values
  - Can affect success of optimization run!
  - Choose values that are initially feasible (flux limit and thermal power requirement met)
  - Multiple runs with different initial values improve confidence of the result
- Initial step size
  - Determines how far the algorithm will jump to assess impact of changing variable values
- Maximum optimization iterations
  - Limits the number of iterations before terminating algorithm
- Optimization convergence tolerance
  - Smaller value implies more iterations before convergence
- Maximum receiver flux (Tower and Receiver page)
  - Flux on receiver evaluated at each iteration to determine feasibility

Optimization Settings	
Initial optimization step size	<input type="text" value="0.06"/>
Maximum optimization iterations	<input type="text" value="200"/>
Optimization convergence tolerance	<input type="text" value="0.001"/>

# Running the optimization

- Run time proportional to number of heliostats
- Can take some time!

```
Finished with notices.

-----
[ 1] 193.458 | 21.6029 | 17.65 || 1126.57 | 724.996 | $4.07227e+008
[ 2] 205.065 | 21.6029 | 17.65 || 1135.07 | 739.003 | $4.10148e+008
[ 3] 193.458 | 22.8991 | 17.65 || 1139.29 | 694.992 | $4.11845e+008
[ 4] 193.458 | 21.6029 | 18.709 || 1137.41 | 700.863 | $4.1189e+008
[ 5] 188.195 | 20.7236 | 17.0378 || 1110.24 | 762.119 | $4.00317e+008
[ 6] 182.23 | 20.0058 | 16.344 || 1094.71 | 788.867 | $3.93855e+008
[ 7] 167.757 | 19.5456 | 14.7312 || 1076.33 | 790.979 | $3.84742e+008
[ 8] 159.48 | 17.1304 | 14.5839 || 1055.49 | 855.401 | $3.76225e+008
[ 9] 163.742 | 16.7101 | 12.5304 || 1037.94 | 994.939 | $3.67923e+008
[10] 147.454 | 15.2777 | 11.5775 || 1029.49 | 1093.53 | $3.62894e+008
[11] 159.663 | 14.4192 | 13.2368 || 1025.53 | 1063.57 | $3.63878e+008
[12] 175.554 | 14.4792 | 14.7801 || 1032.9 | 1062.58 | $3.68685e+008
[13] 148.142 | 14.4856 | 13.354 || 1030.74 | 1010.67 | $3.65606e+008
[14] 138.593 | 13.7948 | 13.5635 || 1033.96 | 1009.83 | $3.66284e+008
[15] 148.117 | 14.384 | 13.0109 || 1028.39 | 1043.86 | $3.6442e+008
[16] 154.417 | 15.4345 | 12.9151 || 1032.73 | 1006.2 | $3.65908e+008
-----

Algorithm converged:
tht= 154.417  rec_height= 15.4345  rec_diameter= 12.9151
Objective: 1032.73

Save log      OK
```

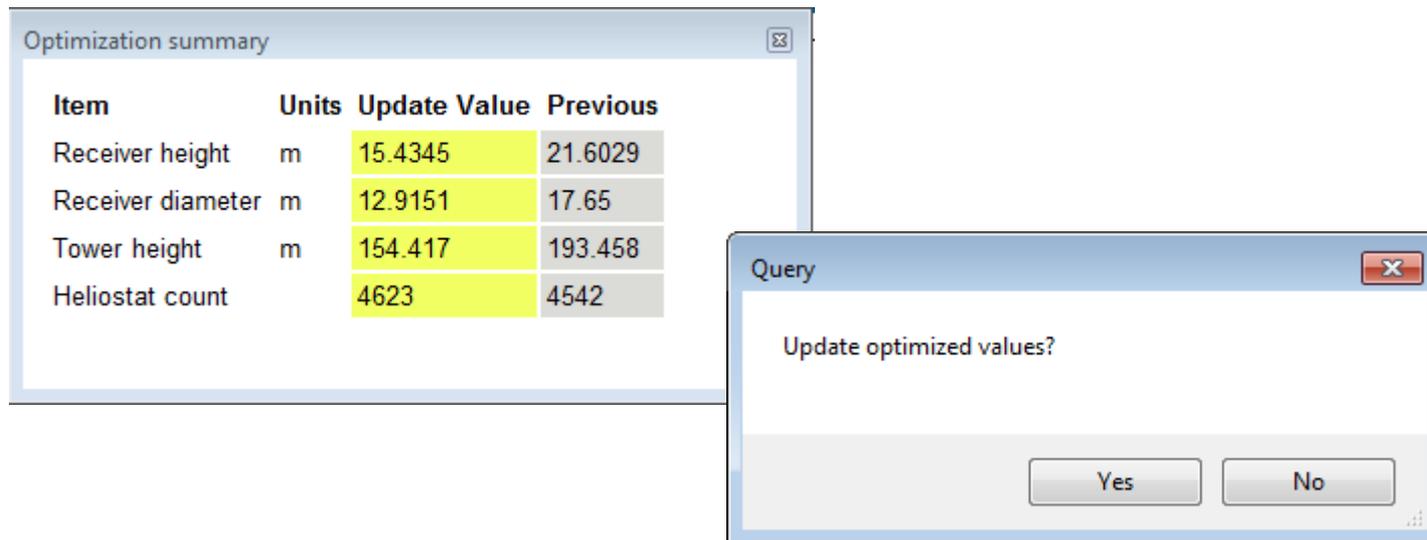
Each line is an evaluation at a design configuration

Tower height | Rec. height | Rec. diameter | Objective | Flux | Plant cost

The final result

# Accepting optimal results

- Results are **not** automatically applied
- You can choose whether to accept the new design



The image shows two overlapping windows from a software application. The top window, titled "Optimization summary", contains a table with the following data:

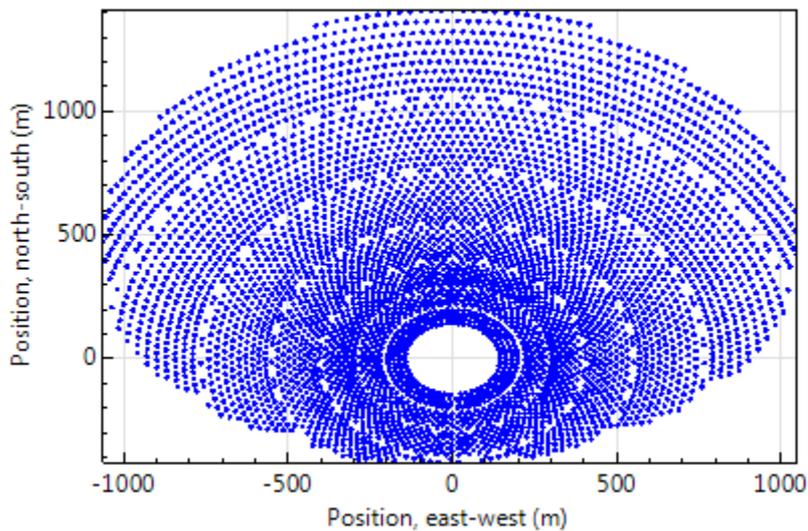
Item	Units	Update Value	Previous
Receiver height	m	15.4345	21.6029
Receiver diameter	m	12.9151	17.65
Tower height	m	154.417	193.458
Heliostat count		4623	4542

The bottom window, titled "Query", contains the text "Update optimized values?" and two buttons labeled "Yes" and "No".

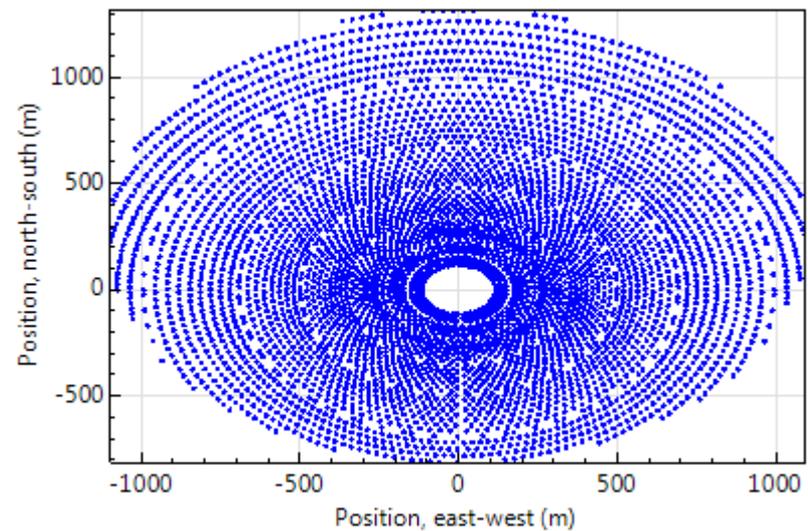
# Generating heliostat layout vs. Optimizing solar field

- Note the difference between optimizing solar field geometry vs. simply updating heliostat positions

Updated



Optimized



# After optimizing...

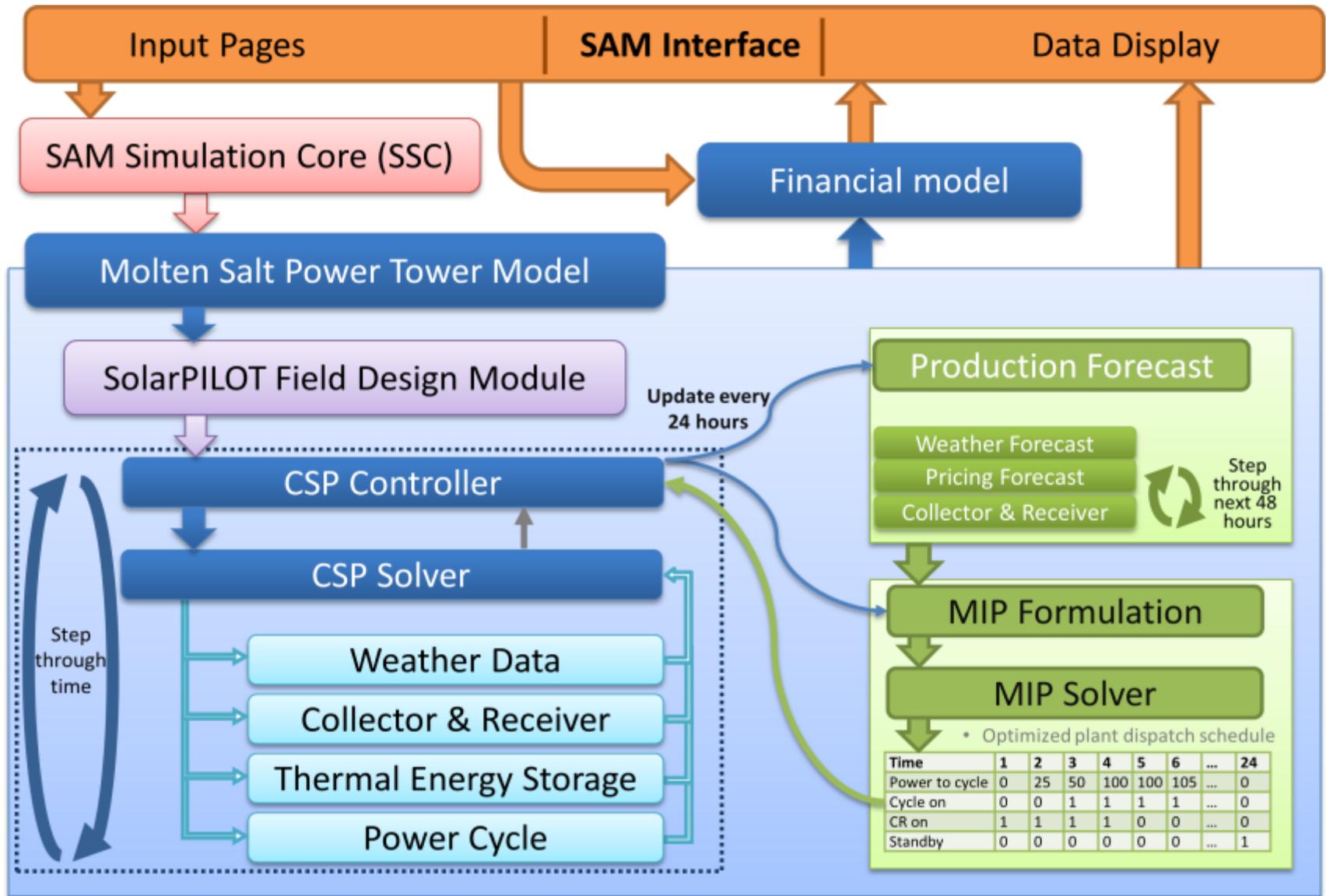
- Check different initial values of tower height, receiver dimensions
- Flux limit can constrain the solution
  - E.g., algorithm “bumps into” flux constraint, and cannot immediately determine whether violation is due to tower height or receiver dimensions
  - Resolve by temporarily relaxing flux limit, starting with different guess values, or decreasing convergence tolerance

# Optimizing dispatch

# Motivation

- Stored energy can be used over a range of possible times
- Determining when and to what extent energy should be used is not straightforward; consider:
  - Production forecast
  - Pricing forecast
  - Component performance and startup behavior
  - Day-to-day operations
- Heuristic approach uses simple rules to decide when to run the cycle
  - Maximizes energy production
  - Operates when energy in TES exceeds minimum needed to run turbine
  - Exhausts TES before shutting down
  - Does not anticipate future use
- Optimized dispatch seeks a revenue-maximizing, cost-minimizing operating profile for both the solar field and power cycle

# How does it work?



# Dispatch optimization settings

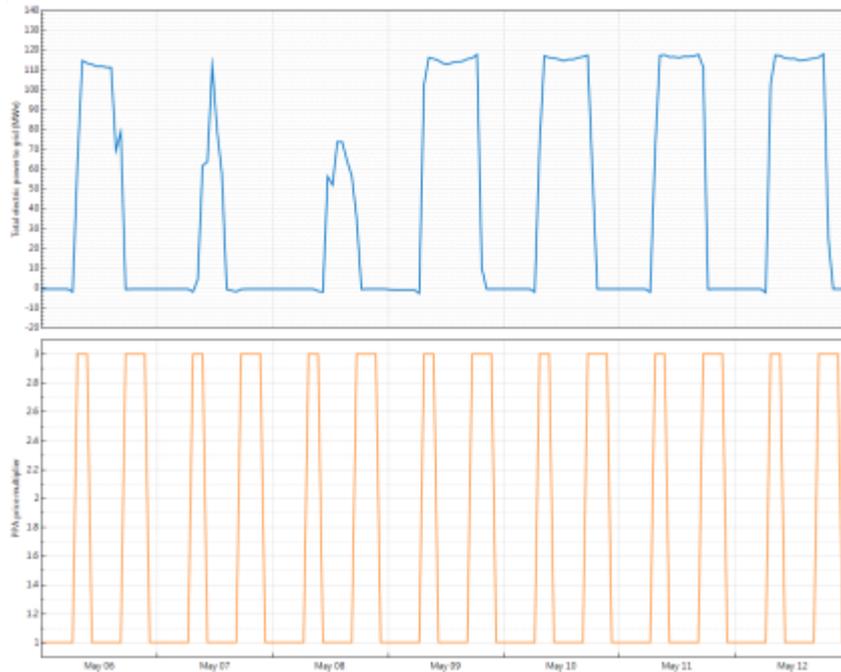
- Time horizon for dispatch optimization
  - Number of future hours considered for each optimization run
- Frequency for dispatch optimization
  - How often is dispatch re-optimized? (Daily recommended)
- Startup cost penalties
  - Cost penalty applied when startup occurs (not included in financial model!)
- Objective function time weighting exponent
  - Decisions at time  $t$  are discounted at the specified rate; e.g., revenue in time  $t=30$  is  $0.99^{30} \approx 0.74$  times that in  $t=0$
- Solver settings
  - Limit number of iterations, optimality gap, or total solver time (expert)
- Max net power to the grid
  - When optimizing, control gross generation to not exceed a net power output limit

## Dispatch Optimization

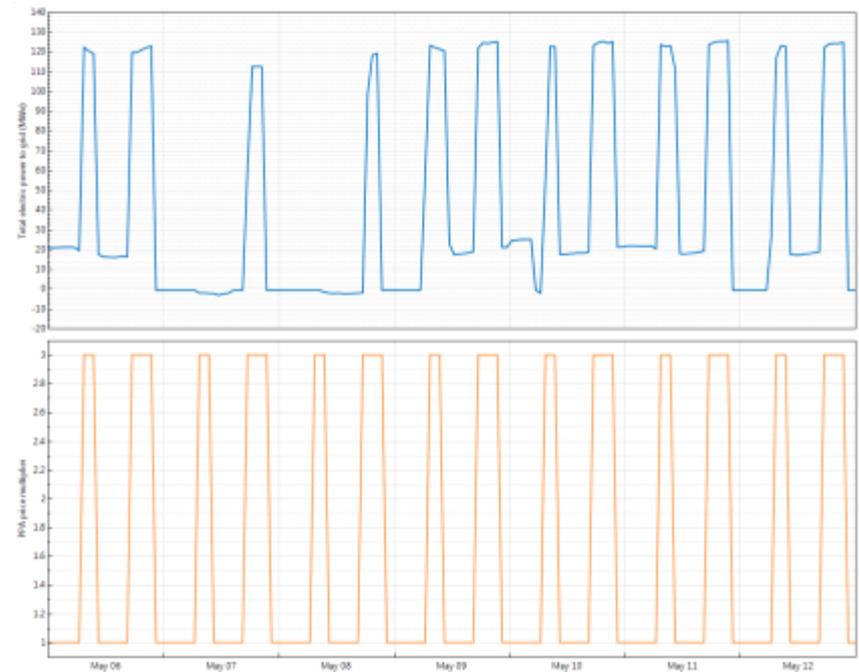
Enable dispatch optimization <input checked="" type="checkbox"/>	Objective function time weighting exponent	<input type="text" value="0.99"/>
Time horizon for dispatch optimization <input type="text" value="48"/> hour	Maximum branch and bound iterations	<input type="text" value="35000"/>
Frequency for dispatch reoptimization <input type="text" value="24"/> hour	Solution optimality gap tolerance	<input type="text" value="0.001"/>
Cycle startup cost penalty <input type="text" value="10000"/> \$/start	Optimization solver timeout limit	<input type="text" value="5"/> sec
Receiver startup cost penalty <input type="text" value="950"/> \$/start	Max. net power to the grid	<input type="text" value="1e+038"/> MWe
Power generation ramping penalty <input type="text" value="0.1"/> \$/ΔkWe	Max. net power to the grid (incl. availability)	<input type="text" value="9.6e+037"/> MWe

# Comparison of performance

## Heuristic



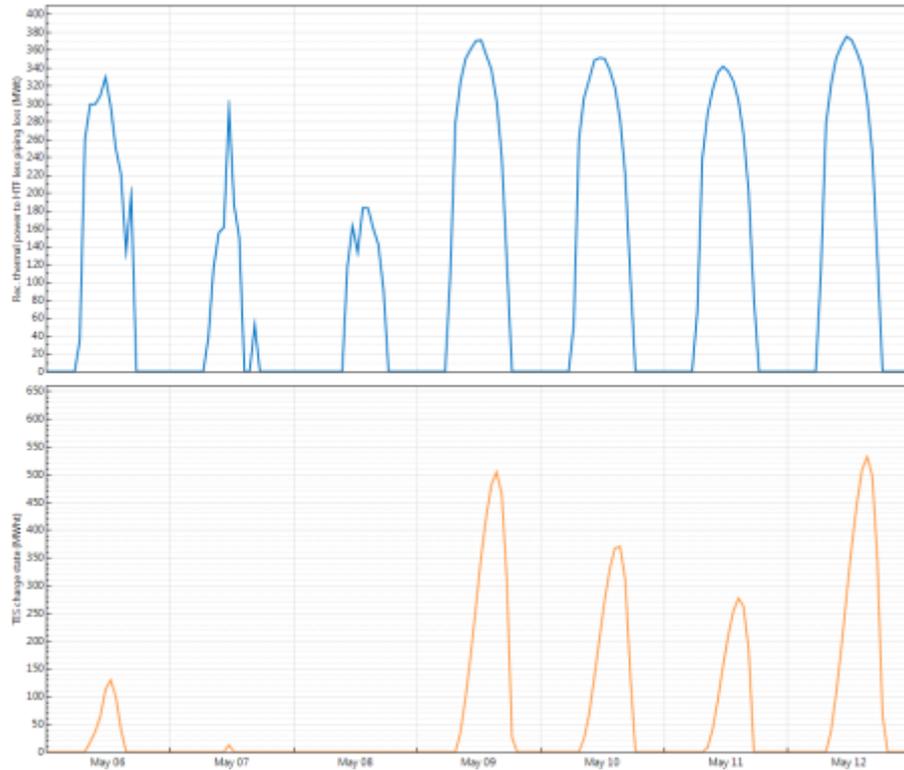
## Optimized



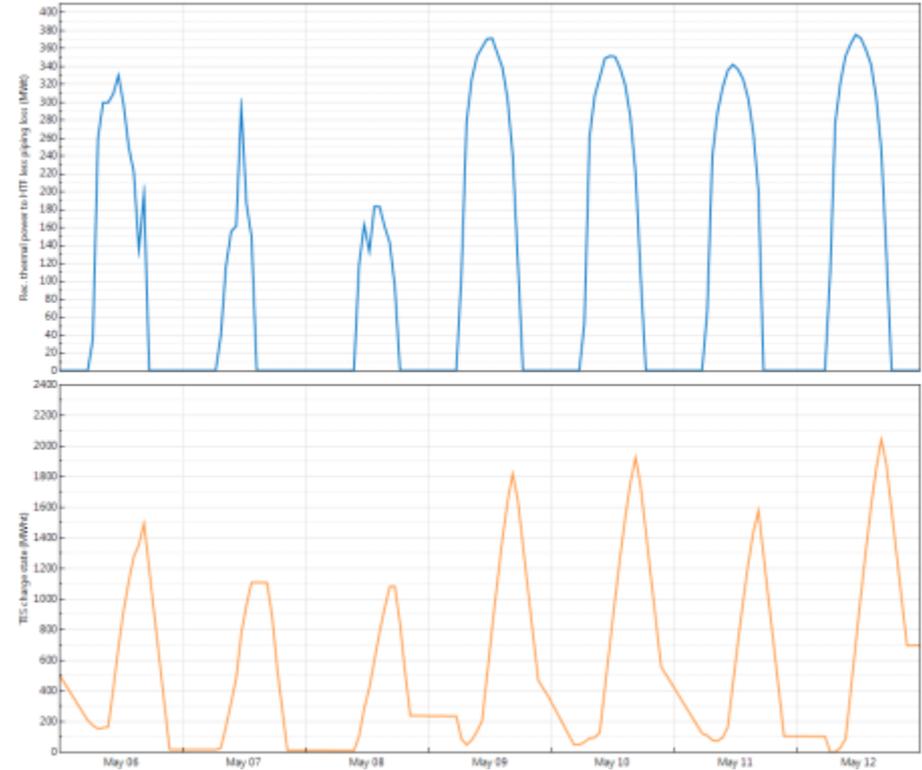
Metric	Heuristic	Optimized
Annual energy (year 1)	301,607,488 kWh	289,253,696 kWh
Capacity factor (year 1)	33.30%	31.90%
PPA price (year 1)	9.59 ¢/kWh	5.96 ¢/kWh
Levelized COE (real)	11.95 ¢/kWh	12.44 ¢/kWh

# TES charge state management

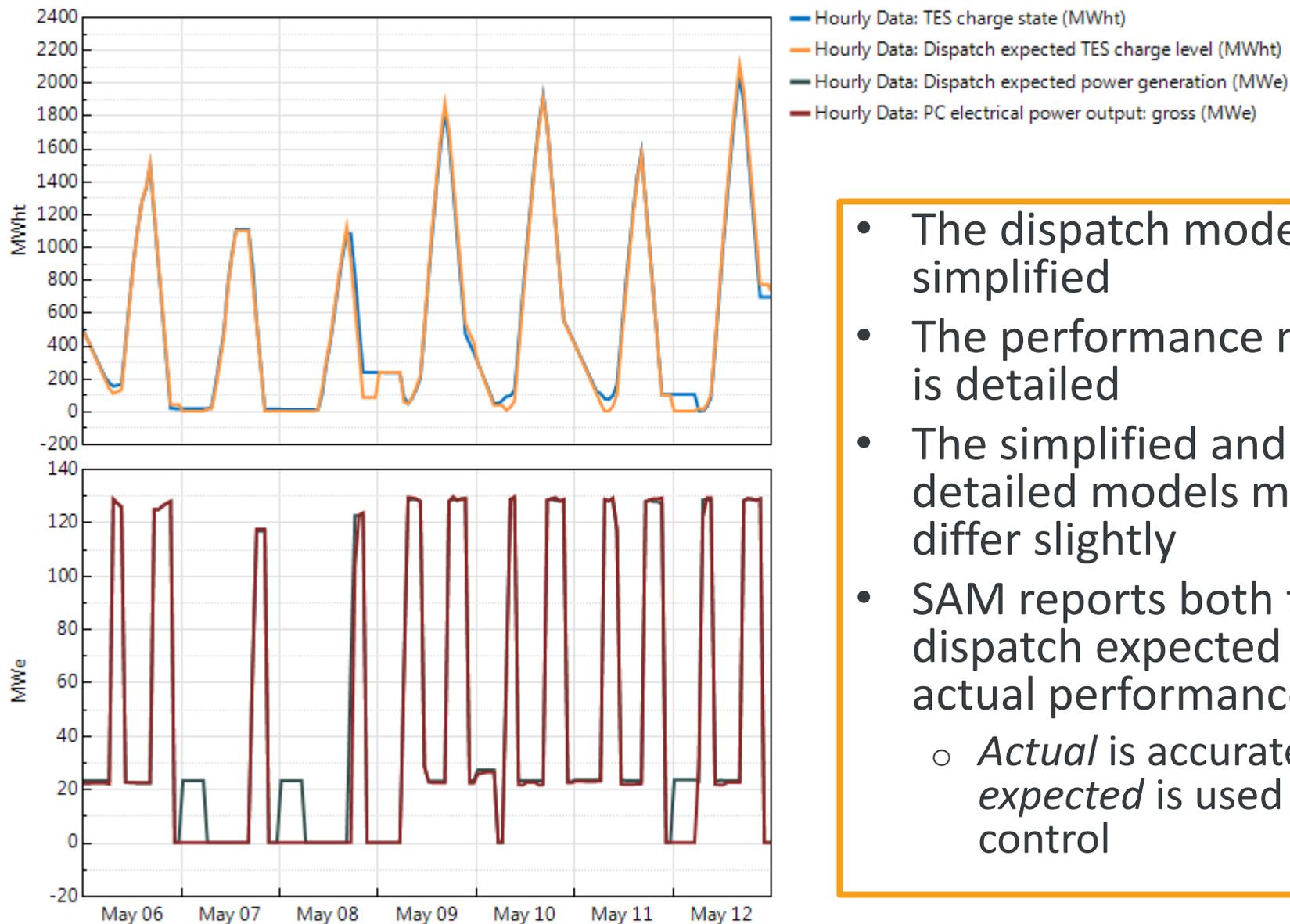
## Heuristic



## Optimized



# Understanding the dispatch projection vs. actuals



- The dispatch model is simplified
- The performance model is detailed
- The simplified and detailed models may differ slightly
- SAM reports both the dispatch expected and actual performance:
  - *Actual* is accurate, *expected* is used for control

# Understanding the simulation log

- If the solver cannot identify a solution for a given day, it reports the error. Each error corresponds to a single day, not the entire simulation!
  - Failed optimization reverts to heuristic dispatch
- A complete log of the optimizer results is shown on the **Notices** tab
- If a large proportion of results are suboptimal or failed, consider modifying solver settings

Finished with notices.

```
Time 1 - 49: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 721 - 769: Dispatch optimization failed: Unbounded problem.
Time 1201 - 1249: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 1345 - 1393: Dispatch optimization failed: Unbounded problem.
Time 2545 - 2593: Dispatch optimization failed: Unbounded problem.
Time 3385 - 3433: Dispatch optimization failed: Unbounded problem.
Time 3841 - 3889: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 4009 - 4057: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 5329 - 5377: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 7633 - 7681: Dispatch optimization failed: Unbounded problem.
Time 8209 - 8257: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
Time 8305 - 8353: Dispatch optimization failed: Unbounded problem.
Time 8521 - 8569: Dispatch optimization failed: Iteration or time limit reached before identifying a solution.
```

```
Optimizing thermal energy dispatch profile for time window 1321 - 1345
Time 1321 - 1369: Optimal solution identified.
Optimizing thermal energy dispatch profile for time window 1345 - 1369
... Unbounded dispatch optimization problem. Retrying with modified problem scaling.
... Unbounded dispatch optimization problem. Retrying with modified problem scaling.
... Unbounded dispatch optimization problem. Retrying with modified problem scaling.
... Unbounded dispatch optimization problem. Retrying with modified problem scaling.
Optimizing thermal energy dispatch profile for time window 1369 - 1393
Time 1369 - 1417: Optimal solution identified.
Optimizing thermal energy dispatch profile for time window 1393 - 1417
Time 1393 - 1441: Suboptimal solution identified.
Optimizing thermal energy dispatch profile for time window 1417 - 1441
Time 1417 - 1465: Optimal solution identified.
Optimizing thermal energy dispatch profile for time window 1441 - 1465
... Unbounded dispatch optimization problem. Retrying with modified problem scaling.
Time 1441 - 1489: Optimal solution identified.
Optimizing thermal energy dispatch profile for time window 1465 - 1489
Time 1465 - 1513: Suboptimal solution identified.
Optimizing thermal energy dispatch profile for time window 1489 - 1513
Time 1489 - 1537: Suboptimal solution identified.
Optimizing thermal energy dispatch profile for time window 1513 - 1537
Time 1513 - 1561: Suboptimal solution identified.
Optimizing thermal energy dispatch profile for time window 1537 - 1561
```

Save log

OK

Thank You!

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